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ENVIRONMENTAL STUDY OF THE SEWAGE OUTFALL AREA AT SAN CLEMENTE ISLAND

An Open-Ocean Sewage Disposal Model

by

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June 1972

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AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

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ADMINISTRATIVE STATEMENT

This report describes an environmental impact study conducted at San Clemente Island to discern the effects of dumping 25,000 gallons daily of raw domestic sewage into the ocean. Sponsored by the Office of Naval Research, the work was accomplished between July 1970 and July 1971 under ONR Project NR 137-885. Major Allen Jewett, Naval Biology, Code 443, was the ONR Program Manager.

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13 ABSTRACT

An environmental-impact study of the San Clemente Island sewage discharge site was used as a model to predict the effects of dumping raw sewage into the open ocean. Coliform bacterial counts, used to assess water sanitary quality, showed that the water at distances greater than several hundred feet from the outfall was within standards for swimming beaches. Biological surveys revealed that plant and animal life was noticeably altered only within about 50 ft from the discharge. In this area there was a paucity of some organisms while others appeared more abundant. Dye-diffusion studies and dissolved-oxygen measurements demonstrated that normal ocean mixing is adequate to prevent oxygen depletion under open-ocean conditions. From an esthetic standpoint, odors and floatable solids were insignificant. The San Clemente Island findings were extrapolated to gauge the effect of ship sewage discharges in the open ocean, with completely harmless results predicted.

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Sewage						
Pollution						
Environmental impact						
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Public health						

SUMMARY

PROBLEM

The disposal of raw sewage into the ocean can produce pollution which may harm the environment and be a health threat to man. Currently, it is common practice to dump raw sewage from ships in the open ocean and from small island facilities. In order to understand the impact of this type of sewage disposal, a study was initiated at San Clemente Island, where untreated sewage is dumped into the ocean at shoreline.

RESULTS

Biological surveys revealed that plant and animal life was altered only within about 50 ft from the discharge site. In this area there was a paucity of some organisms, while several others were more abundant. Coliform bacterial counts, used to assess water sanitary quality, showed that distances greater than several hundred feet from the outfall were within standards for swimming beaches. Dye-diffusion studies and dissolved-oxygen measurements demonstrated that normal oceanic mixing is adequate to prevent oxygen depletion under open-ocean conditions. From an esthetic standpoint, odors and floatable solids were insignificant. The San Clemente Island findings were used to extrapolate to ship sewage discharges in the open ocean with completely harmless results predicted.

RECOMMENDATIONS

The discharge of untreated sewage from San Clemente Island does not appear to present a pollution hazard. However, it is recommended that the discharge pipe be extended offshore to remove the discharge from the shoreline environment where it is currently being dumped. Also, a screen or comminutor is suggested to eliminate floatable solids, which have been occasionally observed. Ships in the open ocean dumping sewage similar in nature to the San Clemente Island discharge should be allowed to dump directly, with the possible exception of requiring screening or pulverization by use of a comminutor to eliminate large floatable solids. However, in areas where mixing is limited, such as bays and harbors, dumping raw sewage may cause pollution.

CONTENTS

INTRODUCTION

As a result of current awareness and concern for environmental preservation, the Naval Undersea Research and Development Center initiated a study to determine the effects on the marine environment of dumping raw sewage from San Clemente Island (SCI). Further studies included an examination of potential public health concerns. The initiation of this environmental impact and public health study was considered immediately essential to gain information for the development of procedures to best preserve the marine environment and protect personnel from infectious diseases associated with raw sewage.

This study was further expanded to serve as an environmental impact model for ship sewage discharge in the open ocean. Discharge from SCI resembles that from a typical middle-size Navy ship in both quality and quantity. Although the quality and quantity are similar, the conditions at SCI represent an extreme ship sewage discharge situation. This is because sewage from SCI exposes a single location continuously, while a ship in the open ocean distributes its discharge over a great distance. Thus, when comparing effects of sewage at SCI to a ship on the high seas, consideration must be made for dilution and time exposure in order to compare the two situations reliably. On one hand, had it been found that the SCI situation presents insignificant "pollution" impact on the marine environment, it would be reasonably safe to infer that in the open ocean the impact would be many times less. On the other hand, had "pollution" been found to occur near the SCI outfall, it would be necessary to consider whether this "pollution" would occur in the open ocean, given appropriate adjustments for dilution and time exposure.

San Clemente Island is owned by the Navy, with facilities centering around Wilson Cove, located on the northeast side of the island. The island is approximately 47 miles from Long Beach and 70 miles from San Diego. The nearest land-based activity is at Santa Catalina Island, about 20 miles to the north (Fig. 1).

The population at Wilson Cove numbers about 300, producing a sewage discharge volume of 25,000 gallons each day. This sewage consists of human wastes, food wastes from the mess hall, pine oil used to disinfect toilets, and detergents from the mess hall and laundry. This sewage is dumped, untreated, from the main outfall (point A, Fig. 2), which has been in operation over 10 years. The discharge site is at shoreline, several feet above mean tide.

Several minor outfalls exist in addition to the main outfall. These are comparatively insiginificant in that each discharges sewage from only one or two toilets. The locations of the minor outfalls are shown in Fig. 2.

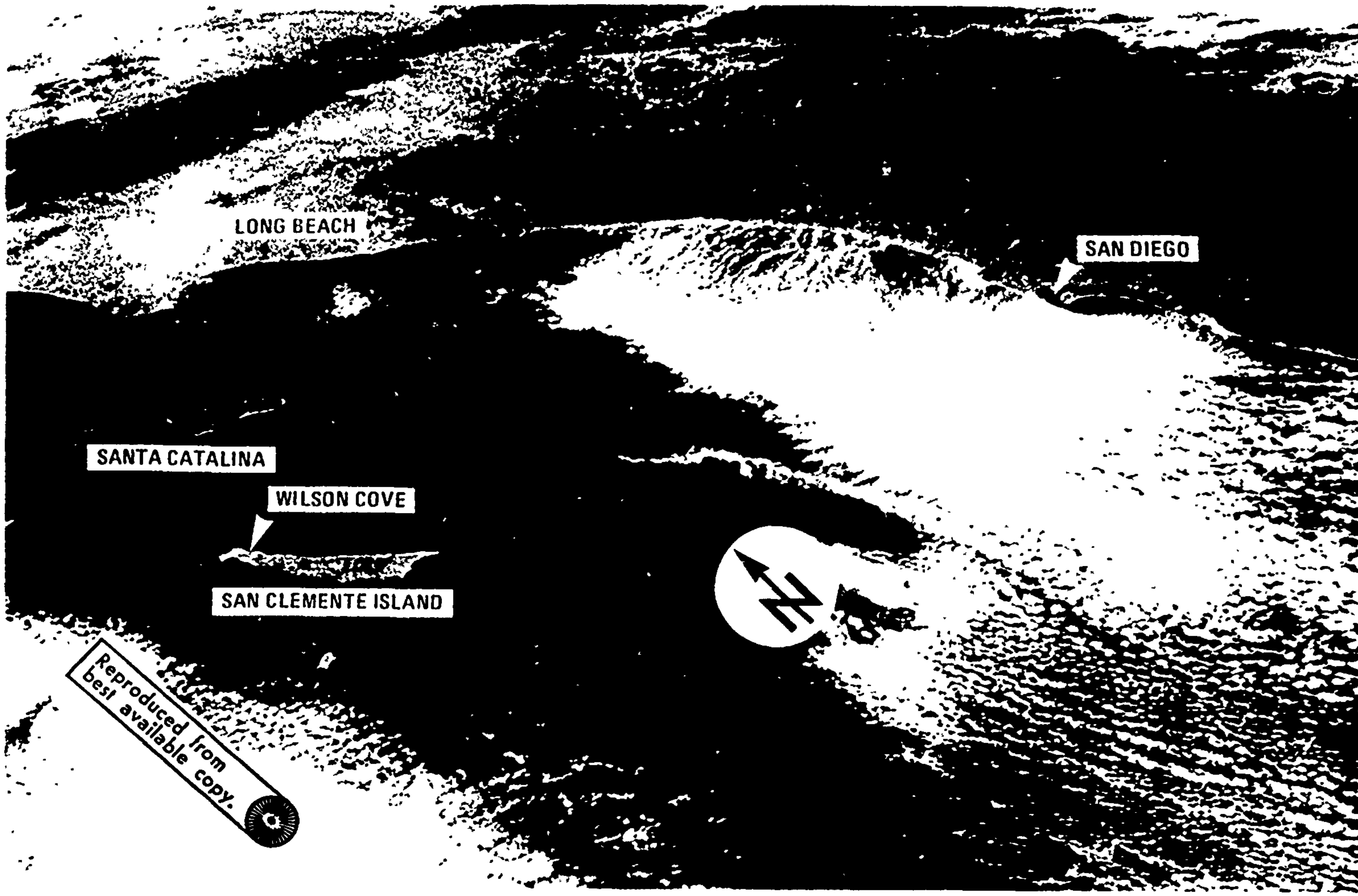

Figure 1. Gemini V photo showing San Clemente Island in relation to the California Coast and Santa Catalina Island. SCI is about 47 miles from Long Beach and 70 miles from San Diego. Photo courtesy of NASA.

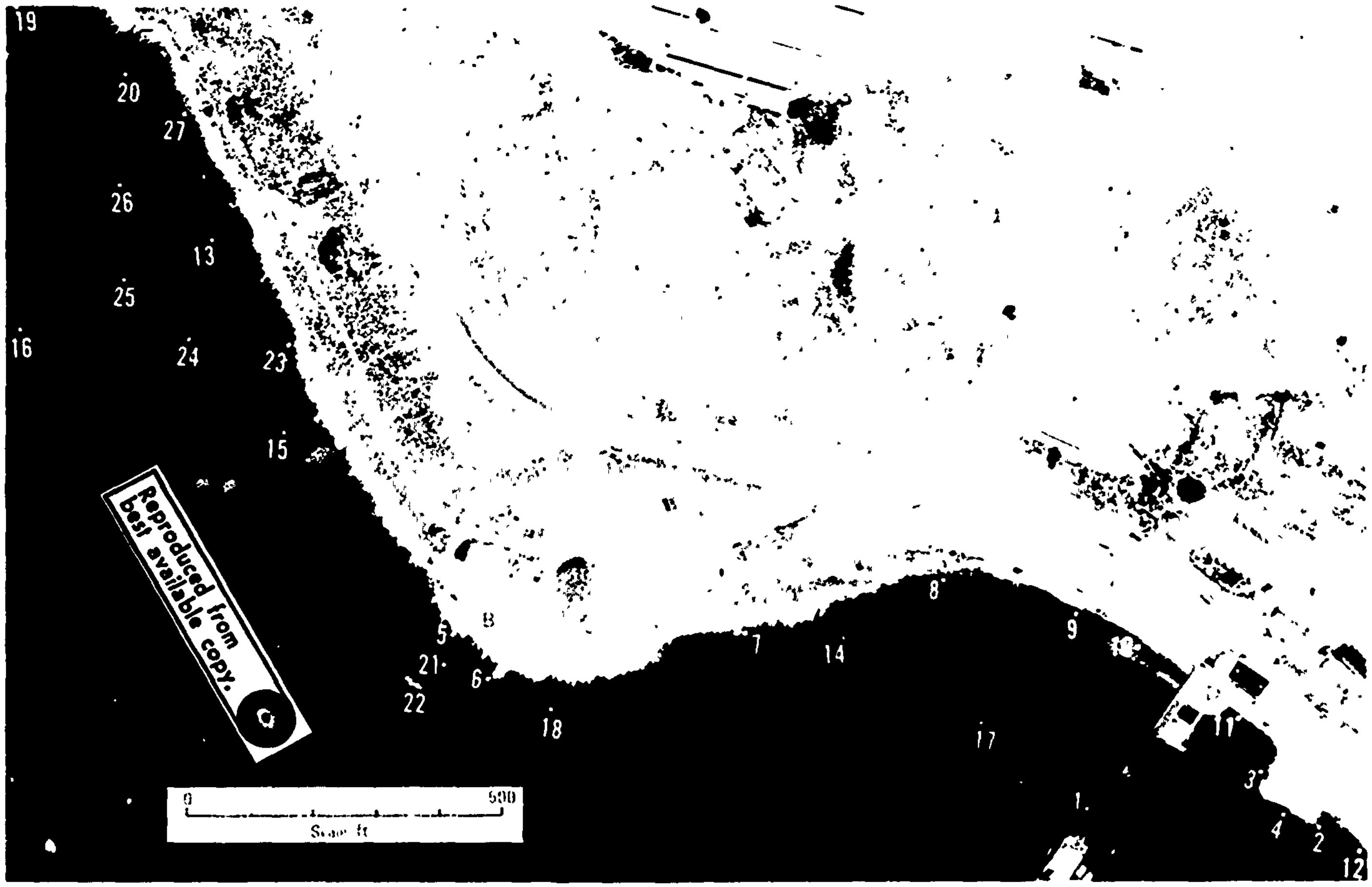

Figure 2. Aerial photo of the Wilson Cove area showing sources of sewage discharge and 27 sites where water samples were collected for total coliform bacterial analysis. The main sewage outfall (A) from the Wilson Cove complex dumps 25,000 gallons of raw sewage each day at the shore line. Two guest cottages dump raw sewage directly into the ocean at the shore at point B. Two toilets exist in buildings which dump raw sewage directly in the beach at C. A single toilet exists in the boat house on Wilson Pier and dumps directly downward into the ocean at D.

CRITERIA FOR SEWAGE POLLUTION

The discharge of large quantities of raw sewage into the ocean may be harmful in some instances, such as in harbors or bays where dilution is limited, while effects may be questionable in the open ocean, where dilution is very great. It is therefore necessary to devise parameters that will allow quantitative determination of what conditions constitute pollution. The terms "pollution" and "raw sewage" have aroused considerable negative public reaction, and opinions vary widely as to what is considered "pollution." McKee (Ref. 1) discussed the need for pollution parameters so that a given condition can be monitored and numbers assigned to objectively evaluate if that condition constitutes pollution. In the discussion, McKee cites a definition used by the California State Water Quality Control Board which defines pollution as any impairment that adversely and unreasonably affects the subsequent beneficial uses of the area. In order for a state of pollution to exist, both adverse and unreasonable changes must be shown, not simply that parameters have been altered to a trivial or superficial extent. The limits for pollution parameters must be detailed so the condition in question can be characterized quantitatively. Unfortunately, few pollution parameters are now available for the marine environment, however, with respect to sewage disposal, three useful parameters are currently in use. These are: the coliform bacterial counts, an index of water sanitary quality; dissolved-oxygen measurements, which indicate the amount of oxygen available to marine life; and measurements of sewage oxygen demands, which show the amount of oxygen required to totally oxidize the sewage. These three parameters are used in this study and are discussed later in this section.

At SCI we are concerned with typical raw, untreated domestic sewage, which consists of human wastes, garbage, detergents, and toilet disinfectants, but no industrial chemicals. The following discussion, consolidated from several references (Refs. 1–9), discusses the impact of domestic sewage in three general areas which may be of concern. These are: public health hazards from sewage-associated disease-causing organisms; harmful impact upon marine life; and undesirable esthetic influences.

PUBLIC HEALTH CONCERNS

Numerous disease-causing (pathogenic) bacteria and viruses may inhabit the intestines of individuals suffering from an active case of certain diseases or of persons who are carriers of these pathogens but who show no symptoms of the disease. Sewage may thus contain pathogenic bacteria and viruses that may contaminate the ocean in the vicinity of a sewage outfall and present a health hazard to individuals in contact with the water. Further, oysters, clams, and scallops concentrate suspended particles in their filter-feeding processes, particles such as detritus, plankton, and sewage-associated pathogens. A consumer eating these sea foods taken from a sewage-contaminated area may thus become infected and develop a serious disease.

. Public health standards have therefore been established to determine if ocean water is safe for human contact and shellfish harvesting. These standards for water sanitation quality are based on the detection of fecal indicator bacteria. These bacteria grow in the intestines of man and, upon identification in water, indicate sewage contamination. Fecal indicator bacteria are used in lieu of detecting the various pathogenic bacteria and viruses directly because it is extremely difficult to show the presence of pathogens. More important is the fact that fecal indicator bacteria are present in sewage in quantities many thousands of times greater than that of pathogens. To insure safe water quality, it is considered adequate by public health authorities merely to show that the fecal indicator bacteria level is substantially low. The reasoning here is that even if several fecal indicator bacteria are detected in the water, it is still considered safe because the probability of contracting pathogenic organisms would be nil, due to the much greater numbers of fecal indicators relative to pathogens.

The two most commonly used fecal indicator bacteria are the coliform group and the fecal streptococci. For water contact areas, such as swimming beaches, concentrations up to 1,000 coliform bacteria per 100 ml of water are considered safe. The bacteriological standards from the California Administrative Code relating to ocean water contact sports areas are included in Appendix A of this report.

IMPACT ON MARINE LIFE

Raw domestic sewage may harm marine life through oxygen depletion, interference by particulate matter, direct toxicity, or the effects of overfertilization. Several detailed biological studies were conducted in the vicinity of several sewage outfalls off the Southern California Coast that dump millions of gallons of sewage daily. The overall effects on marine life appeared insignificant even though some alteration may have occurred in the immediate discharge area (Refs. 5–8). If, in a given situation, an impact on marine life can be demonstrated, the magnitude must be considered in order to discern if the effect is significant.

The presence of sewage may result in the depletion of oxygen from the ocean if the sewage is present in sufficient quantities for long enough periods. Oxygen depletion is brought about by microorganisms naturally present in sewage and seawater as they utilize dissolved oxygen in the ocean to oxidize the sewage. Sewage discharges will not cause oxygen depletion if the discharge quantity is limited and dilution and mixing in the ocean are adequate to provide an abundance of oxygen for the microbial oxidation process. However, in areas such as bays and harbors, where dilution and mixing are limited and sewage is allowed to accumulate, oxygen may be substantially depleted.

The concentration of dissolved oxygen in unpolluted surface ocean water is generally between 7 and 8 mg/l. When the concentration is below 2 mg/l, fish and other organisms may be inhibited or killed from oxygen deficiency. If the water into which wastes are being dumped can be shown to contain at least 5 mg/l of oxygen, the water can be considered safe for marine life, and no pollution exists from the standpoint of oxygen depletion.

Solid material in sewage may become deposited on the ocean floor, causing oxygen depletion for sediment-dwelling animals, or particulate debris can harm algae attached to nearshore rocky areas. Several bottom studies have been conducted off the Southern California coast near outfalls of treated sewage; however, because of the large volume, a residue of solids was deposited on the ocean floor near each outfall terminus. Marine life was found to be altered, but not eliminated, close to each terminus (Refs. 5–8). Particulate matter was shown to be harmful to algae when particulates were present in quantities sufficient to smother reproductive stages or produce turbidity that limited light (Refs. 7, 9).

Domestic sewage may contain soaps, detergents, and household disinfectants. If these materials are present in sufficient concentrations, marine plants and animals may be killed. These materials are usually present in such small amounts that toxic effects are not likely except on organisms in the immediate vicinity of the discharge.

Harmful effects from overfertilization is another potential concern. It is possible that an abundance of nutrients provided by sewage may stimulate "red tide" blooms, which is a condition in which certain toxic marine microorganisms multiply in great numbers and may deplete oxygen from the water. This oxygen depletion can be harmful to marine life, and the toxins from the organisms themselves can be fatal to certain species. Filter feeders like mussels and clams concentrate this toxin while feeding. Consumption by humans of toxins in such concentrations can produce fatal results.

The abundance of nutrients added from the Hyperion sewage treatment plant off Santa Monica, California, is apparently not related to "red tide" conditions which occur periodically and naturally along the California coast (Ref. 5). The possibility of harmful effects from overfertilization from sewage discharge does not seem a concern in these waters.

ESTHETIC QUALITIES

The discharge of untreated raw sewage (and even treated sewage in some instances) may produce objectionable odors, floatable solids, turbidity, and greasy surface slicks. These alterations of the marine environment may or may not accompany detrimental effects on marine organisms, but should be prevented for esthetic reasons.

FINDINGS

PUBLIC HEALTH

Fecal indicator bacteria were enumerated on membrane filters by means of standard (Refs. 10, 11) collection, handling, and culture procedures (see Appendix B). For most water quality surveys the total coliform count is sufficient as an indication of sanitation. However, fecal indicator bacteria die more rapidly in the ocean than in fresh water, thus decreasing the number of bacteria capable of detection. For this reason, three fecal indicator groups (the total coliforms, total fecal coliforms, and total fecal streptococci) were compared

for relative abundance and survival in seawater to gain information as to which group would be most useful for an indicator of sewage pollution in the sea.

Sewage was collected directly from the SCI outfall and a small portion added to seawater collected far from the outfall. This mixture of sewage and seawater was added to sterile 1-liter flasks, which were then incubated at 4°C, 12°C, and room temperature (25°C). Samples were taken immediately in duplicate to determine the initial number of each of the three fecal indicator groups. Samples were subsequently taken at 12, 24, and 48 hours to measure die-off. The flasks were agitated vigorously before samples were removed in order to suspend bacteria which may have settled or attached to the walls of the jar.

Figure 3 shows the relative numbers of the three fecal indicator groups and their die-off characteristics at three temperatures. The total coliform group was shown to be initially more abundant than the fecal coliform group or total fecal streptococci at 0 time and at subsequent samplings. The total coliform group was therefore chosen as the most sensitive indicator of fecal contamination, since this group is present in greatest numbers upon immediate sampling or after greater exposure to seawater when stored at 4 to 25°C. The lower temperatures were most satisfactory to minimize die-off and were used in transporting samples to the mainland laboratory.

Water samples were taken at various locations near the outfall and Wilson Cove to estimate the sanitary quality. Figure 2 shows the sites at which water samples were collected for total coliform bacterial analysis. Water samples were transported to the mainland, and within 12 hours after collection all samples were membrane filtered in duplicate and added to nutrient medium. Table 1 shows the mean total coliform counts corresponding to the sample locations in Fig. 2.

Two detailed studies were conducted in the immediate vicinity of the main sewage outfall to demonstrate total coliform distribution in the surface water. Samples were collected directly below the discharge and at distances of 50, 100, 200, and 300 ft along the shoreline, perpendicular to the shoreline and an estimated 45 deg between shoreline and the perpendicular (Figs. 4 and 5). Samples for the 30 June 1971 study were assayed on the mainland within 12 hours from time of collection (Fig. 4). The study was repeated on 7 July 1971 with samples filtered and added to nutrient plates on the island within 4 hours from the time of collection (Fig. 5). All samples were assayed in duplicate and the mean value plotted.

A study was performed to determine if solid surfaces had a concentrating effect on coliform bacteria. Algal fragments and slimes on rock and pier pilings were collected. An estimated 2 to 5 ml volume of each material was placed in a jar containing 10 ml sterile seawater and agitated vigorously to remove attached bacteria. A portion of this water was then tested for coliform bacteria and the number of coliforms contained in the 2 to 5 ml of slime or algal fragments calculated. A concentration factor was calculated from the number of total coliforms per volume of slime, or algae, divided by the number of coliforms found in an equal volume of seawater surrounding each solid surface studied (Table 2).

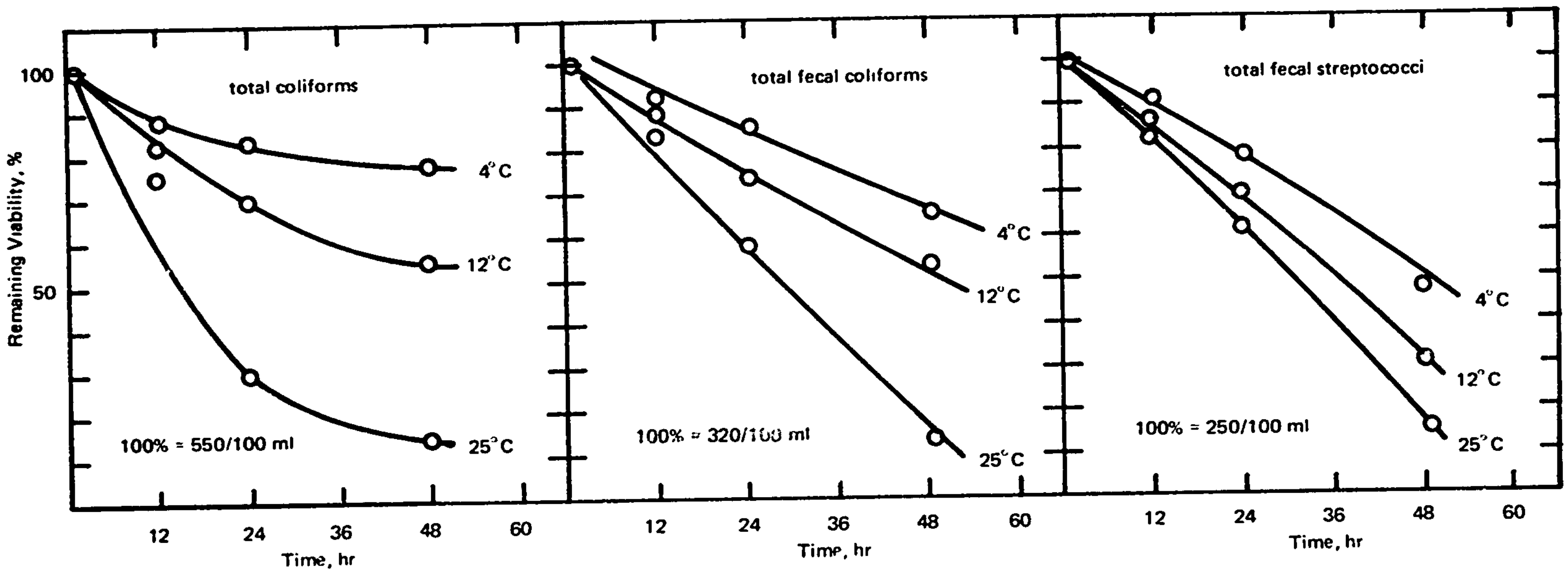

Figure 3. Percent remaining viability of three bacterial groups used to assess water sanitary quality when exposed to sea water at 4°C, 12°C, and room temperature (25°C). At 0 time the water contained 550 total coliform bacteria per 100 ml; 320 fecal coliform bacteria per 100 ml; and 250 fecal streptococci per 100 ml.

Table 1. Total coliform bacteria in the Wilson Cove area corresponding to numerical surface sample locations depicted in Fig. 2.

Location (see Fig. 2)	Date collected	Total coli-forms per 100 ml*	Location (see Fig. 2)	Date collected	Total coli-forms per 100 ml*
1	4-15-71	22	14	4-26-71	1
	5-21-71	15			
	6-4-71	1	15	4-26-71	4
	6-11-71	0			
	7-20-71	2	16	4-26-71	0
2	6-4-71	175	17	12-22-71	8
				4-15-71	119
3	6-4-71	62			
	6-11-71	30	18	4-26-71	2
4	6-4-71	63	19	12-22-70	2
	6-11-71	56		4-15-71	1
	7-20-71	0		4-26-71	2
5	6-4-71	1	20	4-15-71	40
6	4-15-71	62	21	12-22-70	1
	5-21-71	113		4-26-71	0
7	6-11-71	61	22	4-15-71	40
8	5-21-71	142	23	4-15-71	105
	6-11-71	32		7-7-71	270
				6-30-71	168
9	5-21-71	1,500			
	6-4-71	39	24	6-30-71	12
				7-7-71	154
10	6-11-71	182			
	7-20-71	50	25	6-30-71	1,550
				7-7-71	1,400
11	5-21-71	1,200			
			26	6-30-71	742
12	4-15-71	25		7-7-71	3,400
13	4-15-71	10	27	6-30-71	20
	4-26-71	10		7-7-71	82

* Each number represents the mean value of total coliform colonies counted on duplicate or triplicate membrane-filtered portions from the same sample.

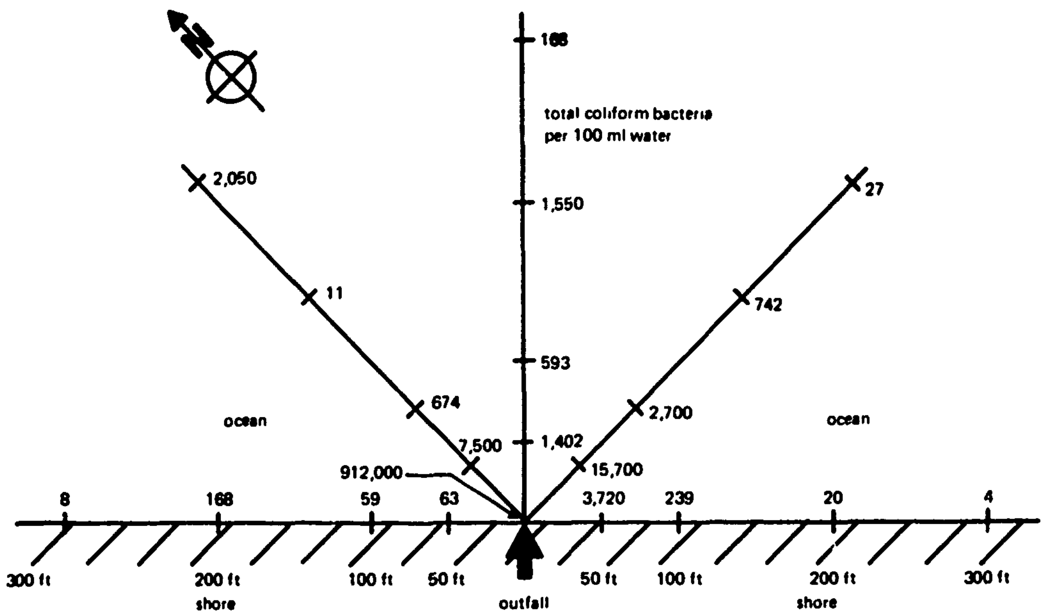

Figure 4. Distribution of total coliform bacteria in surface water within a 300-ft radius from the main sewage outfall. Water samples were cultured for total coliform bacteria per 100 ml seawater within 12 hours from time of collection by means of standard membrane-filter culture techniques. Values given represent the mean of duplicate samples (30 June 1971).

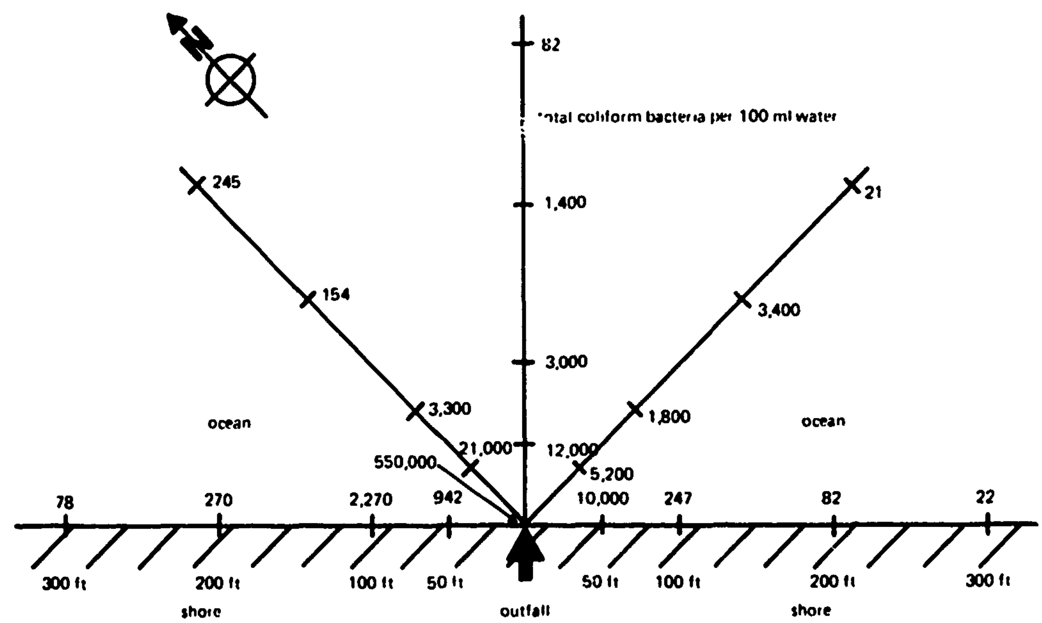

Figure 5. Distribution of total coliform bacteria in surface water within a 300-ft radius from the main sewage outfall. Water samples were cultured for total coliform bacteria per 100 ml of seawater within 4 hours from time of collection by means of standard membrane-filter culture techniques. Values given represent the mean of duplicate samples (7 July 1971).

Table 2. Incidence of total coliform bacteria on surfaces.

Surface	Approximate location (see Fig. 2)	No. total coliforms per 2-5 ml of surface material	No. total coliforms per 100 ml of surrounding water	Conc. factor*
Algae	4	358	5	1400
Slime	9	1500	53	5600
Slime	1	275	2	2700
Kelp	21	3	1	60
Kelp	26	230	122	38
Kelp	25	90	42	43

* Concentration factor (CF) calculated assuming 5 ml of surface material

$$CF = \frac{\text{No. total coliforms per 5 ml of surface sample}}{\text{No. total coliforms per 100 ml of surrounding seawater}} \times 20$$

IMPACT ON MARINE LIFE

The marine life in the outfall area was studied during periods of high and low tides, by onshore observations and subtidally by diver surveys. Two comparative transects were made to identify intertidal benthic algae during low tide.

Close-up examination at the point of discharge revealed large numbers of crabs and limpets which appeared attracted to the discharge area. Seagulls were occasionally observed near the outfall terminus (Fig. 6). Observations at low tide indicated that certain algal species were absent within a radius of about 50 ft from the terminus; however, beyond 50 ft the algal growth appeared luxuriant.

Diver surveys showed an abundance of marine life directly off the outfall. Figure 7 shows the abundance of algae and fish about 50 ft directly out from the outfall. Large numbers of jack smelt were often observed within 1 ft of the outfall at high tide, apparently attracted to and feeding on the sewage (Fig. 8).

An underwater survey was made by marine ecology consultants experienced in determining sewage discharge effects. These investigators surveyed the outfall area looking for abnormalities caused by the sewage discharge. Only within a radius of about 50 ft from the outfall could definite changes due to sewage be detected. Beyond this distance, the flora and fauna appeared more luxuriant than in similar coastal zones. Three fish species were observed schooling abundantly in the effluent. A list of these fish and other organisms identified in the outfall area is given in Appendix C.

Another group of consultants conducted a quantitative survey of the intertidal zone at low tide by analyzing benthic algal communities. Line transects were run immediately beneath the outfall and at a location 150 yd to the south of the outfall. The results of this survey, presented in Appendix D, revealed that some species of benthic algae were not present immediately below the outfall compared to an area 150 yd away.

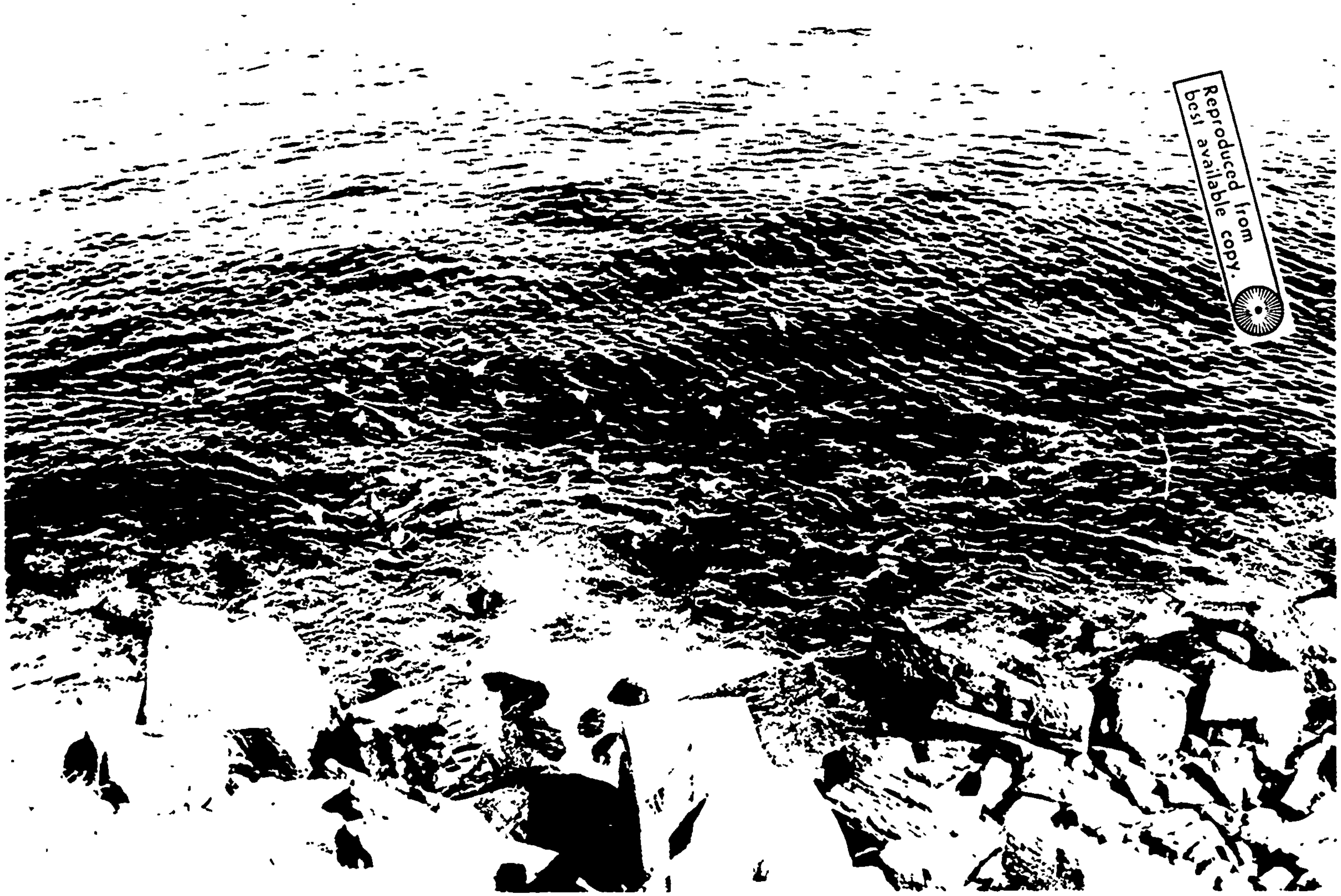

Figure 6. Seagulls in relation to the sewer outfall pipe

Figure 7. Photo taken in 10 ft of water 50 ft from the main outfall showing the abundance of fish and algae.

ESTHETIC QUALITIES

The SCI outfall area has been observed over many days from locations directly at the point of discharge at the shoreline and from the cliffs above. No grease films or floatable materials were evident except occasionally when a paper towel or other resistant object was observed floating on the surface. Figure 9 shows the outfall and absence of floatable matter in the vicinity. No fecal matter or toilet paper is observed floating on the surface. These materials were fragmentated in the outfall pipe before discharge. The fragmented sewage components produce a noticeable turbidity up to about 20 ft from the discharge point. Odors were slight in the immediate vicinity of the discharge site, but were generally undetectable several hundred feet away.

DYE DIFFUSION AND SEWAGE DILUTION

In order to demonstrate the amount of sewage dilution and subsequent lowering of the oxygen demand of the raw sewage in the SCI outfall area, a dye-diffusion study was initiated. Rhodamine WT was added continuously at a constant flow rate at the end of the outfall pipe. The continuous dye discharge produces a semi-steady-state condition, which is the most meaningful procedure to estimate sewage dilutions at various distances from the discharge site. The steady-state condition is the most valid estimation since dilution by continuous oceanic mixing and the constant addition of sewage, or dye, are taken into account.

By determining the dye dilution at a sample location and knowing the dye and sewage discharge volumes, the corresponding sewage dilution can be calculated. Water samples were taken and measured for dye fluorescence in an Aminco-Bowman Spectrofluorometer. Dye concentration was estimated based on a standard curve, which was found to be linear in the range from 2 ppb to 2 ppm (550-μ excitation, 578-μ emission). Sewage dilution calculations for distances up to 300 ft from the outfall are presented in Appendix E.

Two dye-diffusion studies were conducted on two separate days. Water movement was generally in a southerly direction during both studies as evidenced by dye movements. Sewage and dye were therefore more concentrated south of the outfall and thus less diluted in this region compared to similar locations north of the outfall. Sewage dilutions generally in excess of 1,000 times were calculated in water beyond 100 ft north and 100 ft south of the entry point at the shoreline and offshore. (See diagram and calculations, Appendix E.)

CONCLUSIONS

PUBLIC HEALTH

The Wilson Cove area, except within a radius of several hundred feet from the main outfall, meets bacteriological health standards for swimming beaches (Appendix A). High coliform counts were detected at sample sites 9 and 11 (Fig. 2), remote from the main outfall, but this is probably attributable to separate sewage discharges from toilets near these sites (discharge sites C and D in Fig. 2).

Figure 9. Discharge site of main sewage outfall showing absence of floatable material.

The present site of the main sewage outfall poses no apparent health hazard because swimming does not occur in the outfall area. Extension of the outfall to a point several hundred feet from shore, near the ocean bottom, would remove sewage from the shore area and should maintain near-shore coliform counts well within swimming beach standards.

Since coliform numbers are so low several hundred feet from the point of discharge, chlorination of the sewage effluent seems of little value. Chlorination is used to kill disease-causing bacteria and viruses; however, the low coliform numbers indicate that the water is of high enough sanitary quality without chlorination.

The study to determine the relative numbers and die-off of total coliforms, total fecal coliforms, and total fecal streptococci indicated that the total coliform group is the most sensitive indicator for sewage contamination in the ocean. For freshwater sources it has been suggested that the fecal streptococci may be a more valid indicator because of their ability to remain viable longer (Ref. 10). In the ocean, however, our study shows that the fecal streptococci are no more resistant to die-off than the coliforms. In addition, the fecal streptococci are significantly more sparse initially. There are, therefore, fewer of them present for detection as pollution indicators. From the standpoint of initial numbers and die-off, the total coliform group appears to be the most reliable of the three fecal indicator groups for the estimation of water sanitary quality in the ocean.

Measurements of coliform bacteria on solid surfaces in the water revealed a greater frequency of these bacteria on the surfaces than in the surrounding water, which indicates that coliform bacteria are concentrated on submerged surfaces. This investigation did not determine if coliforms on surfaces remained viable longer than coliforms suspended in the sea or if multiplication is possible on solid surfaces. These two questions should be considered to better understand this effect. The fact that coliform bacteria are present on solid surfaces in increased numbers is of interest for two reasons. First, these bacteria may be removed from the water by concentration on surfaces, such as suspended particulate matter, kelp, or slimes on rocks and other objects. A modification of the standard coliform counting techniques could be extended to expose a submerged filter surface to the coliforms in seawater and to estimate the number of coliforms attached over a given time period. Secondly, the increased number of coliform bacteria found on solid surfaces relative to the surrounding water may be useful in certain instances for pollution monitoring. Slimes from surfaces or algal material may provide useful coliform numbers showing sewage contamination even though the number of coliforms in the surrounding water may be indeterminable because of intermittent sewage discharge, current patterns, etc.

IMPACT ON MARINE LIFE

The only alteration in marine life that was caused by sewage discharge from the main SCI outfall occurred within a radius of about 50 ft. This small influence is believed to be a result of continuous direct exposure to toilet disinfectants and detergents rather than human wastes. Beyond this distance, any effects from the sewage appeared to be beneficial rather than harmful, as evidenced by a luxuriant flora and fauna. Even in the intertidal zone some

of the invertebrates around the outfall area seemed to be larger and more abundant than in areas removed from the sewage discharge.

Oxygen depletion is not a problem even immediately at the discharge site. Oxygen measurements showed the concentration to be about 6 mg/l directly at the point of discharge and 7 mg/l just 50 ft away (Appendix D). Although the oxygen demand of water at the discharge site may be high, continuous mixing with fresh seawater prevents oxygen depletion in this small area. On many occasions at high tide, when the sea is 1 ft below the point of discharge, hundreds of smelt can be observed directly under the outfall, apparently feeding. Marine life is not threatened by oxygen depletion in the outfall vicinity.

Sedimentation of sewage solids was not observed in the outfall vicinity. Mixing appears adequate to keep particulate sewage components in suspension, thus removing solids from the area.

The impact on marine life presented by the SCI sewage discharge appears insignificant. It is therefore concluded that there is no pollution hazard with respect to marine life. Even though the existing outfall does not seem to present a significant threat to marine life, extending the outfall further from the shore would eliminate sewage contact with marine life close to shore. The location of the discharge point should take into account the outlying kelp beds to insure that harmful sewage concentrations do not threaten them. Further alteration of the SCI sewage disposal system appears unnecessary.

ESTHETIC QUALITIES

The SCI sewage outfall does not appear to present a problem with respect to objectionable esthetic qualities. Except for an odor which exists close to the site of sewage discharge, no significant objectional qualities were found. Turbidity of the ocean at the site of discharge was increased only in a small area, and therefore not considered significant. Floatable solids were not obvious except for an occasional paper towel which resisted fragmentation in the outfall pipe. Resistant floatable materials can be eliminated by placing a comminutor in the sewage line or by the use of filter screens. An extension of the outfall pipe below the water would eliminate the present existing view of sewage discharge onto the rocks below the outfall and would eliminate turbidity and odors at this site.

SEWAGE DILUTION AND OXYGEN DEMANDS

An important parameter in domestic sewage characterization is the amount of oxygen that is required to oxidize the sewage. This is the oxygen demand of sewage and is important because it indicates the amount of oxygen which will be depleted from the water into which the sewage is dumped. If too much oxygen is removed, marine life will be killed.

Oxygen is removed as a result of microorganisms which oxidize the sewage. The process is termed "biochemical oxygen demand" (BOD). This oxygen demand is measured

by the amount of oxygen which is depleted from sewage samples incubated for 5 days at 30°C. A more rapid estimate of oxygen demand is the chemical oxygen demand (COD) technique, which is the amount of oxygen needed to bring about complete oxidation of al. organic matter by chemical oxidation procedures in the laboratory. The COD is higher than the BOD for the same sewage sample since the former is a complete oxidation, while BOD is only the partial oxidation brought about by microorganisms. In ordinary sewage disposal conditions, however, the BOD is a more realistic estimate of the oxygen demand imposed by discharged sewage since bacterial oxidation is the primary means of oxygen removal. The same sewage can be tested for COD and BOD to obtain a correction factor to convert other COD measurements directly to BOD. This is done where large numbers of samples are involved since COD measurements are more easily performed than BOD.

Oxygen demand measurements were made on SCI raw sewage (Appendix F) and found to have a BOD of about 250, which is typical for raw sewage. This means that 1 liter of raw sewage will require 250 mg oxygen for microbial oxidation. Since seawater contains at most 7 to 8 mg oxygen per liter, it is apparent that virtually all oxygen would be removed, and marine life killed, if the sewage were mixed with only several liters of seawater. On the other hand, if the sewage is diluted 100 times with seawater, the resulting oxygen demand would be 2.5 mg oxygen per liter. This lowered oxygen demand will remove only 2.5 mg oxygen from 1 liter of seawater, which naturally contains from 7 to 8 mg oxygen. Therefore, the oxygen content of seawater would be lowered to about 5.5 mg per liter, which is safe for most organisms. Further, if the sewage is diluted several hundred or thousand times, the BOD would be less than 1 mg oxygen per liter, which would be completely safe for all marine life.

It should be noted that BOD is based on 5 days incubation at 30°C. In the open ocean, the water is continually mixing; thus even though seawater is calculated to have a given BOD after sewage dilution, the BOD is not an immediate one. Mixing provides fresh seawater with high oxygen concentrations, and the low sea temperature (about 12°C) means oxygen is removed at a very slow rate by the microorganisms. BOD values greater than the natural oxygen content of seawater are of significance only in areas where mixing is limited, such as in bays or harbors. In the open ocean, however, mixing is sufficient to dilute most sewage loads adequately.

The sea state at SCI during the dye-diffusion studies was quite calm, compared to the choppy conditions which usually prevail. The dye-diffusion and sewage-dilution calculations are therefore likely minimum values. Even so, sewage was calculated to be diluted several thousand times just 100 ft from the outfall. Oxygen demands at this distance from the outfall would be insignificant.

Dissolved-oxygen measurements were performed directly below the outfall and found to be about 6 mg per liter. Water 50 ft directly offshore from the outfall contained about 7 mg oxygen per liter, which approximated values measured for water removed from the outfall site (Appendix D).

It is concluded that the SCI outfall poses no problem with respect to oxygen depletion.

EXTRAPOLATION OF SCI TO SHIP DISCHARGE

The SCI study can be used to predict possible harmful impacts of raw sewage disposal from a ship in the open ocean. The comparison is a conservative one because greater potential harmful effects would be expected at SCI as a consequence of the increased sewage residence time at SCI, which would not be encountered by a ship enroute in the open ocean.

The SCI outfall, which dumps sewage from the island's 300 inhabitants, can be compared directly to a middle-class navy ship having a similar population and sewage type. The SCI study revealed that there were no significant harmful effects from the standpoints of harm to marine life, public health concerns, or adverse esthetic qualities. It can therefore be assumed that sewage disposal from a middle-class navy ship in the open ocean would impose even less impact and thus be completely harmless.

The SCI findings can be further extrapolated to estimate the impact from a maximum open-ocean ship discharge, that from an aircraft carrier with a complement of about 3,000. This is roughly 10 times the number on SCI. Assuming a tenfold linear relationship to the SCI study, several predictions can be made. First, if the coliform counts at SCI were increased 10 times just 300 ft from the outfall, the numbers in most cases would still be within public health sanitary limits for swimming beaches. Secondly, assuming a tenfold increase, sewage dilutions just 100 ft from the SCI outfall would still be sufficient to completely dilute the sewage adequately and negate the possible threat of oxygen depletion.

Thus, it is concluded that any ship on the high seas dumping domestic sewage similar in nature to the SCI discharge will present no harmful effects to the marine environment or impose a public health threat. It is recommended, however, that ships in the open ocean adequately pulverize sewage by use of a comminutor before discharge to eliminate the possibility of floatable solids.

VALUE OF SEWAGE TREATMENT IN THE OPEN OCEAN

The nature of the various sewage treatment processes should be considered and understood in order to avoid unnecessary and excessive treatment. Sewage treatment is necessary when large amounts of sewage are discharged into inland or near-shore ocean waters. However, some kinds of treatment may be of little or no value in situations involving open-ocean disposal of sewage from small populations. The general treatment processes and value of each are summarized below:

> Primary treatment: This process involves the removal of solids by settling or screening. Solids can be harmful because this material removes oxygen from the body of water into which the sewage is discharged (high oxygen demand). Solids may also settle to the bottom, hindering marine life or producing objectionable turbidity in the water.

Secondary treatment: During this treatment the oxygen demand is lowered further by aeration, which causes oxidation of fine particles and dissolved organic matter not removed by primary treatment. This is done to minimize the amount of oxygen removed from the body of water into which the sewage is discharged.

Chlorination: Chlorination is a public health precaution. The purpose is to kill disease-causing bacteria and viruses which may be present in sewage.

As concluded by this study, there is no apparent need for sewage treatment for open-ocean discharge from a small population such as SCI or a ship in the open ocean for the following reasons:

Primary treatment: We have been unable to detect any harm from the discharge of solids. Solids are fragmented into small particles by mixing in the discharge pipe and dissipated rapidly by mixing with the sea. There was no bottom sedimentation detected, and oxygen was not harmfully removed since mixing was adequate to dilute the sewage. Primary treatment does not seem necessary except for a screen or comminutor to remove or pulverize occasional resistant solids, such as paper towels.

Secondary treatment: Mixing and dilution of sewage is adequate to prevent significant oxygen depletion. Secondary treatment would therefore be of no value.

Chlorination: Based on the coliform index for water sanitary quality, areas beyond a 300-ft radius from the outfall are within swimming beach quality. Chlorination does not seem necessary except in near-shore areas, where there is water-contact recreational activity or where shell-fish are cultivated. Shell-fish (oysters and scallops) concentrate particulate matter, including disease-causing organisms which may be present in sewage, and may thus infect the consumer.

Based on the above considerations, it is concluded that the need for sewage treatment under open-ocean discharge conditions is of questionable value. Except for filters or a comminutor to remove or pulverize floatable sewage solids from ships in the open ocean, the need for additional treatment seems unnecessary.

Appendix A

LAWS AND REGULATIONS RELATING TO OCEAN WATER-CONTACT SPORTS AREAS

(Excerpts from the California Administrative Code 1958, Title 17, Register 58, No. 3, 2-22-58)

Article 2. Definitions

7952. Public Water-Contact Sports Area Defined. Public water-contact sports area means any area so designated (1) by a regional water pollution control board, or (2) by any other authorized and responsible public agency.

7953. Public Beach Defined. Public beach means any bathing place on ocean and bay waters together with adjacent shore areas and any buildings and appurtenances used in connection therewith, to which the public is invited to engage in water-contact sports.

7954. Safety Program Defined. Safety program means a program planned to meet local needs and to minimize the hazard of injury and drowning and to render succor to persons in distress.

7955. Refuse Defined. Refuse means domestic or industrial garbage, trash, or other debris not of sea origin.

Article 3. Sanitation

7956. Sanitation. Every public beach and public water-contact sports area shall be maintained in a clean condition free of refuse. The collection and disposal of refuse and the provision and maintenance of public toilets shall be in a manner approved by the local health officer.

Article 4. Healthfulness

7957. Physical Standard. No sewage, sludge, grease, or other physical evidence of sewage discharge shall be visible at any time on any public beaches or water-contact sports areas.

7958. Bacteriological Standards. Bacteriological standards for each public beach or water-contact sports area shall be as follows:

Samples of water from each sampling station at a public beach or public water-contact sports area shall have a most probable number of coliform organisms less than 1,000 per 100 ml. (10 per ml.); provided that not more than 20 percent of the samples at any sampling station, in any 30-day period, may exceed 1,000 per 100 ml. (10 per ml.), and provided further that no single sample when verified by a repeat sample taken within 48 hours shall exceed 10,000 per 100 ml. (100 per ml.).

Bacterial analysis shall be made in accordance with procedures recommended by the 10th edition of the *Standard Methods for Examination of Water and Sewage* of the American Public Health Association. The combinations of portions planted on lactose broth as a presumptive media shall be at least two (2) 1.0 ml. portions, two (2) 0.1 ml. portions, and two (2) 0.01 ml. portions. All portions showing gas within 48 hours shall be confirmed on brilliant green bile broth.

7959. Bacteriological Sampling. In order to determine that the bacteriological standards specified in 7958 above are being met in a water-contact sports area designated by a water pollution control board in waters affected by a waste discharge, water samples shall be collected at such sampling stations and at such frequencies as may be specified by said board in its waste discharge requirements.

In waters of a public beach or water-contact sports area that has not been so designated by a water pollution control board, water samples shall be collected at such sampling stations and at such frequencies as may be determined by the local health officer or the State Department of Public Health. Local health officers shall be responsible for the proper collection and analysis of water samples in such areas.

7960. Corrective Action. When a public beach or public water-contact sports area fails to meet the standards as set forth in 7957 or 7958 above, the local health officer or the State Department of Public Health, after taking into consideration the causes therefor, may at his or its discretion close, post with warning signs, or otherwise restrict use of said public beach or public water-contact sports area until such time as corrective action has been taken and the standards as set forth in 7957 and 7958 above are met.

NOTE: This code was written in 1958 citing the 10th edition of *Standard Methods* for procedures of bacterial analysis. The 13th edition, currently in print, superseding the 10th edition, discusses the membrane filter technique as an approved method. The membrane filter technique was used in the SCI study.

Appendix B

TECHNIQUES FOR BACTERIAL ENUMERATION

U. S. Public Health Service approved methods for the enumeration of bacteria in water quality are given in Refs. 10 and 11. Membrane filter techniques for the three fecal indicator groups used in this study are summarized below:

TOTAL COLIFORM ANALYSIS

1. All equipment is sterilized and standard aseptic technique used as per *Standard Methods* (Ref. 10)

2. The water sample is vacuum filtered through a standard 0.45-μ membrane filter.

3. The walls of the funnel are washed with 50 ml of sterile phosphate buffer and filtered.

4. The filter membrane is transferred aseptically to a sterile plastic petri dish containing a sterile absorbent pad saturated with 1.8 to 2.0 ml of MF-Endo Broth (Difco), or M-Coliform broth (BBL).

5. The petri dish is inverted and incubated at 35°C for 24 hr.

6. Colonies with a greenish metallic sheen are counted as coliforms.

FECAL COLIFORM ANALYSIS

1. Identical filtration techniques are employed as for total coliform analysis.

2. The medium was prepared from the following formula:

Rosalic Acid Reagent	0.01%
Tryptose (Difco)	1.0%
Proteose Peptone No. 3 (Difco)	0.5%
Yeast Extract	0.3%
Sodium Chloride	0.5%
Lactose	1.25%
Bile Salts No. 3	0.15%
Aniline Blue	0.01%

3. A sterile absorbent pad is placed into a petri dish with 2.0 ml of medium and the membrane filter added.

4. Plates are sealed with waterproof tape, or sealed water-tight in a plastic bag and submerged in a waterbath at 44.5°C for 24 hr.

5. Blue colonies are counted as fecal coliforms, whereas gray to cream-colored colonies are non-fecal coliforms.

FECAL STREPTOCOCCI ANALYSIS

1. Water samples are filtered as in the other procedures.

2. The membrane filter is placed on M-Enterococcus Agar (Difco, or BBL) which has been poured and solidifed in petri dishes, and incubated at 35°C for 48 hr.

3. Red or pink colonies are counted as enterococci.

Appendix C

SPECIES OBSERVED AT WILSON COVE'S SEWER OUTFALL, SCI*

by

Wheeler J. North, California Institute of Technology, Pasadena
Alec R. Strachan, Southern California Edison

PLANTS

Chlorophyta

Bryopsis
Chaetomorpha
Codium
Ulva

Phaeophyta

Coilodesme corrugata
Colpomenia
Cystoseira neglecta
Dictyopteris zonarioides
Dictyota binghamiae
D. flabellata
Egregia
Eisenia arborea
Halidrys
Hydroclathrus
Macrocystis pyrifera
Pachydictyon coriaceum
Pelagophycus giganteus
Sargassum
Zonaria farlowii

Rhodophyta

Acrosorium
Anisocladella
Chondria
Corallina officinalis
C. Pinnatifolia
C. vancouveriensis
Gelidium nudifrons
G. purpurascens
Gigartina armata
Gymnogongrus
Haliptilon
Laurencia splendens
Leptocladia
Lithophyllum lamellatum
Lithothamnion
Lithothrix aspergillum
Plocamium pacificum
P. violecium
Polysiphonia
Pterochondria
Pterocladia
Rhodymenia californica
Scinaia

ANIMALS

Porifera

Astylinifera
Cyamom argonl
Ficulina
Halichondria
Haliclona (2 spp)
Hymenamphiastra
Isociona
Leucosolenia eleanor
Microciona
Myxilla
Tedanione

Coelentrata

Aglaophenia
Astrangia
Cerianthid
Eugorgias
Lophogorgias
Muricea californica

Annelida

Diopatra
Platynereis
Sabellidae
unident. tubes

Bryozoa

Bugula
Crisia?
Hippodiplosia?
Lagenipora?
Phidolopora
Rhyncozoon
Scrupocellaria
Thalamoporella

Mollusca

Aletes
Conus
Haliotis fulgens
Navanax
Norissia

Arthropoda

Balanus tintinnabulum
Chthamalus
Panulirus
unident. crab
unident. *amphipos*

Echinodermata

Centrostephanus
Linkia
Parastichopus
Pisaster giganteus
Strongylocentrotus franciscanus

Chordata (Tunicata)

Didemnum
Euherdmania

Chordata (Pisces) - Fish -

Atherinops affinis (School)
Brachyistius
Caulolatilus
Chromis
Coryphopteris nicholsi
Embiotoca jack
Girella nigricans (School)
Heterodontus
Hypsypops
Lythripnus
Mediluna
Oxyjulis californica (School)
Paralabrax clathratus
Phanerodon
Pimelometopon
Scorpaena
S. atrovirens
Sebastes chrysomelas?

* July 16, 1971
Time: 0930-1130
Depth: to 45 ft

Appendix D

INTERTIDAL ECOLOGY, CHEMICAL AND PHYSICAL MEASUREMENTS AT THE SCI OUTFALL AREA

Prepared by Steven N. Murray, Donald B. Bright, and Robert Sims
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In an effort to determine the effects of discharged effluents on the biology of the intertidal regions adjacent to the outfall, intertidal benthic algal communities were analyzed. Line transects were run on 27 June 1971 at two locations: (1) immediately beneath the outfall, with the transect line laid as an extension of it, and (2) at a location of comparable topography and exposure to wave action approximately 150 yd to the south of the outfall. The major benthic algal species were determined along each transect and the results of these determinations form a tentative species list (Table D-1).

These findings revealed that a number of species were absent from the line transect located below the outfall. The most notable of these species were *Gigartine canaliculata, Laurencia pacifica, Lithothrix aspergillum* and *Rhodoglossum affine*, common components of the intertidal area analyzed to the south of the outfall. Algal coverage on the transect line below the outfall was primarily composed of a dense growth of a small unknown species of *Ulva* and a dark brown-black algal mat of entangled *Ectocarpoid* and blue-green algal filaments. The total number of macroscopic algal species observed along the transect line below the outfall was much reduced when compared with the number of species recorded along the transect line south of the outfall. A reduction in total number of species is very common in areas subjected to sewage discharge and is frequently employed as an indication of environmental stress. The area most obviously affected, as determined by qualitative observation, appeared to be confined to a relatively small region surrounding the outfall pipe. However, further studies are needed before the quantitative information necessary to determine the full extent and degree of the effects of the effluent discharged from the outfall can be obtained.

In addition to the aforementioned biological studies, chemical and physical measurements of temperature, dissolved oxygen, salinity and pH were performed with the use of a Martek Mark II water-quality analyzer, and of phosphate-phosphorous and nitrate-nitrogen with the use of a LaMotte Oceanographic Kit. Water samples collected from three sites were analyzed: (1) immediately below the outfall; (2) 50 ft directly offshore from the outfall; and (3) at a location 150 ft offshore, 200 ft to the south of the outfall (see Table D-2). These findings are of a preliminary nature in that additional observations over an extended period of time are necessary before fully meaningful statements can be derived from physical data.

Table D-1. Tentative algal species list.

Species	Transect Location: South of outfall	Transect Location: Below outfall
Colpomenia sinuosa	x	x
Corallina chilensis	x	
Corallina vancouveriensis	x	x
Dictyota flabellata	x	
Dictyopteris zonarioides	x	
Egregia laevigata	x	
Eisenia arborea	x	x
Gelidium coulteri	x	x
Gigartina canaliculata	x	
Gigartina armata/spinosa	x	
Halidrys dioica	x	
Laurencia pacifica	x	
Lithothrix aspergillum	x	
Macrocystis pyrifera	x	
Petrospongium rugosum	x	
Pterocladia capillacea	x	x
Plocamium pacificum	x	
Ralfsia sp.	x	x
Rhodoglossum affine	x	
Sargassum sp.	x	
Ulva sp.	x	x
Zonaria farlowii	x	
Brown algal mat composed of entangled *Ectocarpoid* and blue-green algal filaments		x
Total species recorded	22	7[a]

[a]Species comprising brown-black mat not included.

Table D-2. Physical measurements (June 27, 1971).

Measurement time	Water samples: Base of outfall at surface		50 ft directly offshore from outfall at surface		150 ft offshore, 200 ft south of outfall: Surface		Bottom (17 to 20 ft)	
	0810 hr	1430 hr	0855 hr	1445 hr	0895 hr	1450 hr	0895 hr	1450 hr
Temperature (°C)*	17.3	18.0	16.0	17.0	16.1	16.5	15.5	14.9
Dissolved oxygen (ppm)*	5.5	6.0	6.0	7.3	6.3	8.0	6.8	7.4
Salinity (ppt)*	30.0	32.0	—	—	32.5	34.0	—	—
pH**	8.1	8.3	8.1	8.5	8.1	8.4	8.3	8.3
Nitrate-nitrogen (ppm)**	1.5	<1.0	<1.0	<1.0	<1.0	<1.0	–	–
Phosphate-phosphorous (ppm)**	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	–	–

* Determined with the use of Martek TDC.

** Determined with the use of LaMotte Oceanographic Kit.

Appendix E

DYE DIFFUSION AND SEWAGE DILUTION CALCULATION

The dilution of sewage at various distances from the outfall was calculated on the basis of dye dilution values found at these locations. The full-strength dye was premixed with seawater and these initial dye concentrations were dumped at a constant flow rate into the discharge as it entered the water.

It is assumed that the dye has the same dispersion characteristics as the sewage. The dye flow rate and subsequent dilution in the outfall vicinity are thus inferred to be linearly related to the sewage flow rate and the sewage dilution. The number of times sewage is diluted (d) at a given sample location is expressed as:

$$d = \frac{C_1 D}{C_2 S}$$

where

C_1 = initial dye concentration

C_2 = dye concentration of ocean diluted sample

D = dye flow rate

S = sewage flow rate

Below is a summary of the constants used to calculate the sewage dilutions (d) for each of the two dye studies.

Experiment	C_1 (ppm)	D (ml/min)	S (ml/min)
18 Aug 71	2.3×10^4	37*	95×10^3 *
25 Aug 71	1.2×10^4	58*	95×10^3 *

* An average value

Table E-1. Dye and sewage dilutions at sample locations.

Sites are as indicated in Fig. E-1. A continuous dye discharge rate was maintained on 18 and 25 August 1971 to simulate a steady-state condition of sewage dilution. Dye discharge commenced at 10:40 and 6:25 a.m., respectively.

Sample (Time and/or location)	Dye concentration (ppb)*	Dye dilution × 10^{-5}*	Sewage dilution*
18 August 1971			
11:22 CS	275	0.84	33
12:20 CS	285	0.81	32
12:45 CS	410	0.57	22
1:30 CS	510	0.45	18
2:58 CS	34	0.68	260
3:00 RS-50	24	0.97	380
3:02 RS-100	12	1.9	750
L-50	0.32	730	28,000
C-50	24	0.97	380
R-50	34	0.68	260
L-100	0.01	0.23	900,000
C-100	0.33	700	27,000
R-100	6.2	37	1,400
L-300	0.052	4,500	170,000
C-300	0.01	23,000	900,000
R-300	5.4	43	1,700
25 August 1971			
6:30 CS	200	0.58	36
7:43 LS-50	0.34	340	21,000
7:43 CS	240	0.48	30
7:43 RS-50	10	11	690
8:15 LS-100	0.048	2,400	150,000
8:15 LS-50	0.70	170	10,000
8:15 CS	290	0.40	24
8:15 RS-50	19	6.1	380
8:15 RS-100	25	4.6	280
9:30 LS-100	3.3	35	2,200
9:30 LS-50	4.3	27	1,600
9:30 CS	160	0.73	44
9:30 RS-50	34	3.4	210
9:30 RS-100	2.9	40	2,400
10:30 LS-100	3.2	36	2,200
10:30 LS-50	8.0	15	890
10:30 CS	215	0.54	33
10:30 RS-50	60	1.9	120
10:30 RS-100	11.4	10	630
12:00 LS-100	4.2	28	1,700
12:00 LS-50	85	14	840

Table E-1 (contd)

Sample (Time and/or location)	Dye concentration (ppb)*	Dye dilution × 10^{-5}*	Sewage dilution*
25 August (contd)			
12:00 CS	93	1.3	77
12:00 RS-50	36	3.2	198
12:00 RS-100	1.4	83	5,100
R-100 30°	2.0	58	3,600
R-200 30°	1.45	80	4,900
L-100 30°	0.31	370	23,000
L-200 30°	0.28	414	25,000

* ±2.4%

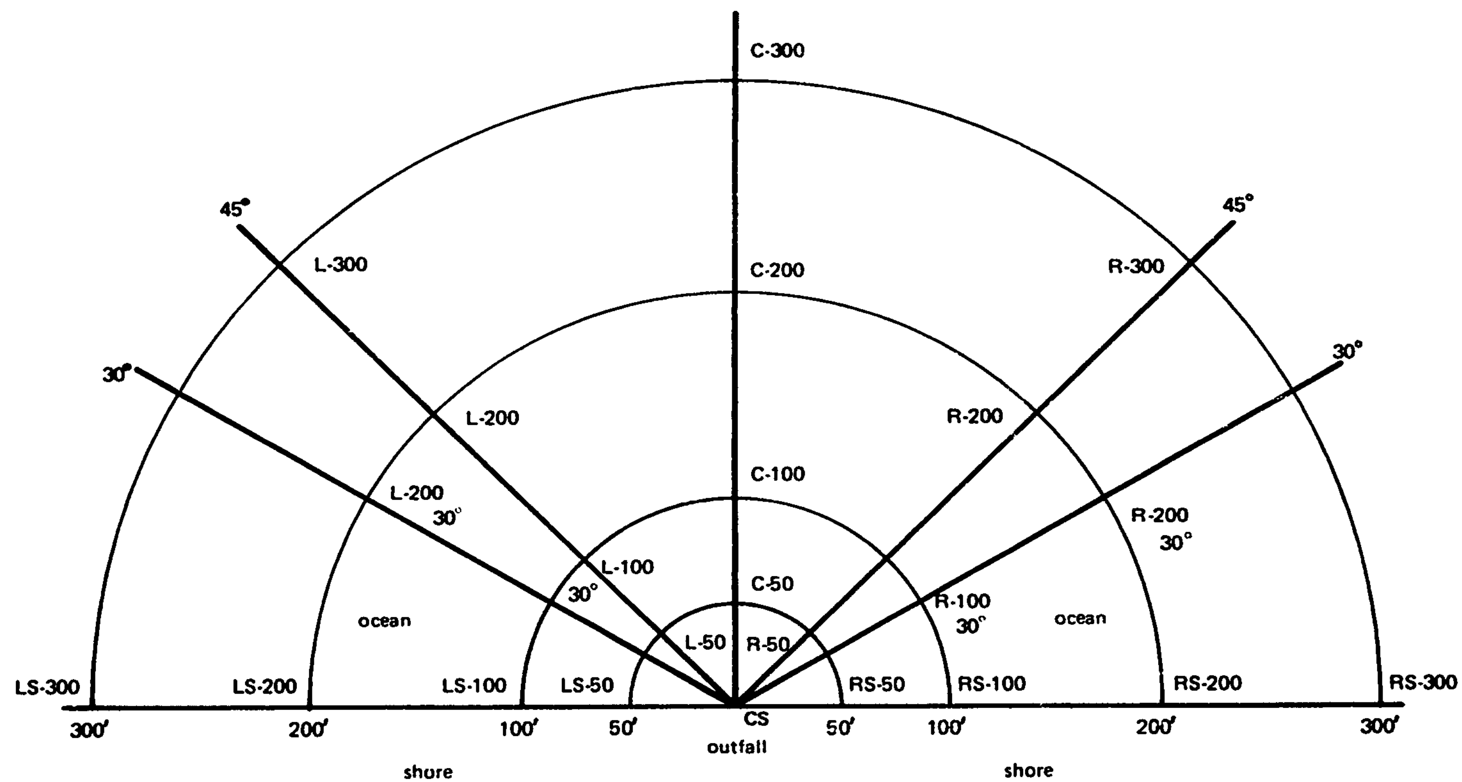

Figure E-1. Sample locations for dye-diffusion studies in relation to sewage discharge site. All samples were collected from the surface, and sample CS was taken directly below the discharge.

Appendix F

OXYGEN DEMANDS FOR SCI RAW SEWAGE*

Raw sewage samples were collected from 1100 to 1950, 16 June and 0600 to 1030, 17 June 1971. Chemical oxygen demand (COD) tests were run on each of the 25 samples of raw sewage, and biochemical oxygen demand (BOD) results were run on three samples in order to determine COD/BOD relationships. Oxygen demands are expressed as mg oxygen per liter.

Time	Actual COD	Actual BOD	Calculated BOD
1135	460		266
1150	700		405
1210	208		120
1236	425		246
1240	400	268	
1310			
1330	325		188
1427			
1500	410		237
1600	380		220
1700	380		220
1720	680		393
1740	460		266
1805	455		263
1823	190		110
1900	510	292	
1940	390		226
1949	460		266
0602	216	90	
0620	280		162
0640	205		119
0700	300		174
0721	250		145
0740	280		162
0800	310		179
0929	520		301
0959	460		266
Avg.	386	217	223

*This oxygen demand data summary was prepared by Perliter and Ingalsbe Engineers, Los Angeles, and submitted with accompanying letter to the Naval Facilities Engineering Command, San Bruno, Calif., dated 7 July 1971.

REFERENCES

1. *Pollution and Marine Ecology*, T. A. Olson, F. J. Burgess, eds., Interscience Publishers, New York, 1967.

2. Federal Water Pollution Control Administration, "Water Quality Criteria," Washington, D.C., 1968.

3. *Water and Water Pollution Handbook*, L. L. Ciaccio, ed., Marcel Dekker, Inc., New York. Vols. 1 to 4, 1971.

4. National Academy of Sciences, "Wastes Management Concepts for the Coastal Zone." National Academy of Engineering, Washington, D.C., 1970.

5. Hyperion Engineers, "Ocean Outfall Design." Sponsored by Holmes and Narver, Inc., Los Angeles, 1957.

6. C. H. Turner, E. E. Ebert, R. R. Given, "The Marine Environment in the Orange County Sanitation District's Ocean Outfall," *Calif. Fish and Game*, 52(1), 1966, pp. 28–48.

7. ————. "The Marine Environment Offshore From Point Loma, San Diego County," Calif. Dept. of Fish and Game Fish Bulletin 140, 1968.

8. J. G. Carlisle, Jr., "Results of a Six-Year Trawl Study of an Area of Heavy Waste Discharge: Santa Monica Bay, California," *Calif. Fish and Game*, 55(1), 1969, pp. 26–46.

9. W. J. North, "Ecology of the Rocky Nearshore Environment in Southern California and Possible Influences of Discharged Wastes," in *Advances in Water Pollution Research*, Vol. 3, E. A. Pearson, ed., Pergamon Press, N. Y., 1964, pp. 247–262.

10. American Public Health Association, Inc., *Standard Methods for the Examination of Water and Wastewater*, 13th Edition, New York, 1971.

11. Millipore Corporation, "Microbiological Analysis of Water," Millipore Application Report AR-81, Bedford, Mass., 1969.